Memory and Discounting: Theory and Evidence[1]

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Abstract:

Adopting the concept of "memory utility" proposed by Gilboa, Postlewaite and Samuelson (2015), we explore the relationship between memory capacity and individual discounting behavior by building a simple two-period model and comparing its predictions with experimental data. The model predicts that in most cases the memorizing capacity should be positively correlated with individual discount rate, which is well supported by the experimental data.

Keywords: Memory Utility, Intertemporal Consumption, Individual Discounting Rates, Time Preference.

JEL Classification: C91, D90.

Introduction

Economic theory typically assumes that people discount future benefits compared to the same amount of benefit that they could enjoy immediately. Two of the main explanations, discussed in the literature, for discounting behavior are impatience (i.e. a time preference) and fear of uncertainty in the future, e.g. risk of death (i.e. a risk preference). Andreoni and Sprenger (2012a, b) argue that time preference and risk preference are different and can be estimated separately, followed by the discussion by Andreoni and Sprenger (2015), Cheung (2015), Epper and Fehr-Duda (2015) and Miao and Zhong (2015).

Memory plays an important role in our behavior, as it is an important factor in shaping our decisions. Compared with psychological literature that has paid ample attention to memory, economic literature only explores this issue in a very limited way. In 1759, Adam Smith (2009, p. 152) observed that "We can entertain ourselves with memories of past pleasures...." which implies that past pleasant memories could yield current utility. Gilboa, Postlewaite and Samuelson (2015) recently developed a new concept known as "memory utility", which connotes that current utility depends not only on the current consumption, but also on past consumption.

Adopting the concept of "memory utility", we attempt to explain the links between memory capacity and individual discounting behavior. If the pleasure enjoyed today generates long-lasting positive memories for the future, which is then added to future utility, an agent who maximizes his/her total utility during their lifetime should naturally allocate more consumption to earlier periods. Memory serves as a premium for consuming today rather than in the future. Therefore, our model predicts that the ability to memorize is positively correlated with discounting, which is supported by experimental data.

This is not the first study looking at utility from memory and discounting. To our knowledge, utility from memory has been discussed by Loewenstein and Elster (1992), together with utility from anticipation. More recently, Gilboa, Postlewaite and Samuelson (2015) set up a complete theoretical framework for introducing memory utility to economic analysis. The purpose of studying this question is to understand a wide class of phenomena that seemingly confront standard economic theory on intertemporal consumption. For example, why do a young couple spend one quarter of their combined annual income on a wedding and honeymoon?

The answer provided by Gilboa, Postlewaite and Samuelson (2015) is that a wedding and a honeymoon are memory goods. While the consumption usually takes place when young, people derive utility from it when they recall it at later stages in their lifetime. Therefore, spending a large amount of money on these non-durable goods may be an optimal choice. However, memory utility may make it harder for people to postpone their consumption and to act as if they have higher discount rate. Their theoretical framework is further developed by Hai, Krueger and Postlewaite (2015) to explain the welfare cost of consumption fluctuations. Our paper takes their idea seriously and argues one step further: if memory makes people behave as if they are more impatient, the elicited discount rate should be positively correlated with the ability to memorize.

The rest of the paper is organized as the followings: Section 2 presents the theoretical framework, Section 3 reports the experimental evidence, and Section 4 concludes.

Theory

- **Benchmark**

We start from a basic two-period consumption model ($t = 0,1$) with a single commodity good. Our model is a simplification of the model of a two-good economy in Gilboa, Postlewaite and Samuelson (2015). The total utility for a consumer is

$$U = u(c_0) + \frac{1}{1+r} u(c_1) \qquad (1)$$

with intertemporal budget constraint:

$$w_0 = c_0 + (1+i)c_1 \quad ; \qquad (2)$$

where $u(c_0)$ and $u(c_1)$ denote the utilities at period 0, and period 1, which are respectively derived from consumption c_0 and c_1. w_0 denotes the total permanent income at period 0; and r and i are the market discounting rate and market interest rate respectively.

Equation (2) is a typical overlapping generations model without involvement of memory goods.

- **Model with memory utility**

Following Gilboa, Postlewaite and Samuelson (2015), consumption at t does not only depend on the current consumption c_t, but also depends on the consumption in the past, which is defined as memory utility. When memory utility is considered, Equation (1) can be rewritten as

$$U = u(c_0) + \frac{1}{1+r} u(c_1, c_0) \qquad (3)$$

If we assume $u(c_1, c_0)$ is additive, and specifically,

$$u(c_1, c_0) = u(c_1) + \rho u(c_0) \qquad (4)$$

where $\rho u(c_0)$ is the memory utility, the utility derived from the memory of $u(c_0)$ at period 1. Here ρ is defined as memory capacity, and $\rho > 0$. In the highly cited paper "The magical number seven, plus or minus two", Miller (1956) finds that human have limited and heterogeneous memory capacities. One can speculate that if a consumer has a better memory, his/her memory utility is higher.

Combining equations (3) and (4) yields

$$U = \frac{1}{1+r}[u(c_0) + \frac{1}{1+r+\rho}u(c_1)] \tag{5}$$

When maximizing the utility in Equation (5) with the budget constraint of Equation (2), the observed discounting rate with memory utility for intertemporal choice becomes

$$r^* = r + \rho \tag{6}$$

Equation (6) implies that when memory utility exists, consumers appear to make decision based on the Observed Discounting Rate r^*, rather than the market discounting rate, as memory utility cannot be observed. Particularly, the observed discounting rate is positively correlated with memory capacity. Thus, we have the following proposition:

Proposition 1:

When a consumer has memory utility, his/her (observed) discount rate is higher when his/her memorizing ability is higher.

The current literature has studied in-depth both memory and discounting rates, but the linkage between them is still missing. The rest of the paper will empirically study the linkage between the two variables via a simple experiment, and then verifies the proposition 1.

Experiment

- Measuring memory capacity

Psychological literature has distinguished three types of memory: sensory, short-term and long-term (Kassin 2006, pp.235). Sensory memory records information from the senses for up to very short time, for example, three seconds. However, sensations that do not draw attention tend to be forgotten, but those we notice are transferred to short-term memory. The short-term memory fades quickly, and only some information turns into long-term memory which can be stored for many years. The information process and the three types of memory are demonstrated in Figure 1.

Short-term memory is the critical chain linking sensory memory and long-term memory, and has been well studied in the literature. It is very difficult to measure sensory memory and long-term memory objectively. As the information processing time is very short for sensory memory, and very long for long-term memory, they cannot be measured accurately. In contrast, psychological literature pays attention to the study on short-term memory capacity. Figure 1 demonstrates that the short-term memory should be correlated with long-term memory capacity.

Limited by attention resources, short-term memory can hold only a small number of items. In the famous memory span task test, Miller (1956) described the human short-term capacity as “the magical number seven, plus or minus two”. In other words, the average length of items that can be recorded in short-term memory is seven, with plus or minus two. His experiment has been replicated on many later occasions, and many studies have found that our short-term memory capacity is actually more limited than what Miller suggested (Cowan 2000). Such an experimental design is widely regarded as a good tool for measuring memory capacity.

Following Miller (1956), Baddeley (1992) and Cowan (2000), a *Memory Span Task* experiment is conducted in this study to measure memory capacity. Our subjects are college students, and are believed to have above average memory capacities. Specifically, we use a computer to generate 13 random number sequences, increasing successively from 2 digits to 14 digits (the number sequences are reported in Appendix 2). Each of the 13 number sequences are put separately on 13 PowerPoint slides, in an order of increasing number of digits, and are shown to the experiment subjects one by one. Each slide is shown for two seconds. Between every second slide a 10-second pause is provided for the subjects to write down the number on the previous slide on a notebook distributed by the experiment conductor. Memory capacity is measured by the number of digits in the longest number sequence a subject is able to write down, before the first mistake is made.

- <u>Measuring discounting rates</u>

Though individual discounting rates cannot usually be directly observed, Coller and Williams (1999) first developed an experiment to elicit this by comparing a list of different payment scenarios with different effective interest rates. We did not combine the time preference elicitation task with the risk elicitation task designed by Holt and Laury (2002) because the paper by Andreoni and Sprenger (2015) and its comments suggest time preference can be elicited without risk preference. From the perspective of the Permanent Income Hypothesis, the discounting rates correspond to the market interest rates.

The method of Coller and Williams (1999) is also adopted in this study for measuring individual discounting rates. Given a table, subjects are asked to choose between two options, A and B. Option A offers 3000 yuan at present, and B offers 3000 yuan plus an interest payments (the list of choices is reported in Appendix 1) The subjects make their choices from 10 rows in which A remains the same and the interest payment for B is increasing. The switching point from A to B is used to calculate the subjects' discount rate. The questions about time preference are hypothetical. Subjects do not receive the money they choose in their answer form.

- Experiment implementation

Our data was collected in 2015 at Nanjing Agricultural University, Jilin Agriculture University, and Jilin University of Finance and Economics in China. We have 587 participants. All subjects are university students, and are recruited by our research partners in these three universities. Such a large sample could yield a robust results from a statistical perspective. The experiments are conducted in the following steps:

Step 1: Collect basic demographic information, such as age and gender of the subjects.

Step 2: Ask the subjects to elicit individual discounting rates using the table in Appendix 1.

Step 3: Show the 13 slides with the number sequences of the memory span task to measure individual memory capacity.

This experiment is also combined with a dictator game, but that was run after the experiment. The total duration of the whole session is typically around 40 minutes, and the subjects receive their payoffs based on their decision in the dictator game.

After deleting abnormal samples, for instance inconsistent answers in eliciting the individual discounting rates, we obtain 559 effective observations.

Experimental Results

The average age of the subjects is 20.77 years, with a standard deviation of 2.20 years. The percentage of male participants is 27.24%. The average number of correct numbers in the memorizing task is 9.31 out of 14, with a standard deviation of 1.78. It is higher than the finding of Miller (1956). However, it is comprehensible as the participants are college students who should have better memory capacity after training and selection of the college-entrance exams in China. The average discount rate is 5.09%, with a standard deviation of 2.60%. [2]

To obtain a quick overview of the relation between discount and memory, we plot the average discount rate at each memory level. Figure 2 shows this plot. There is strong indication of a positive correlation between the two variables. We also show the average discount rate by age and gender. There is an indication of a negative correlation between age and discount rate, and the average discount rate is higher for men than for women.

Next, we regress the discount rate on memorizing ability, age and gender.

$$\delta = \beta_0 + \beta_1 memory + \beta_2 male + \beta_3 age + \epsilon$$

The estimated output is reported in Table 1.

Based on the results, higher memorizing capacity is associated with higher discount rate and the coefficient is significant at a level of 5%. The dummy variable for men is positive, and the coefficient for age is negative. Both coefficients are significant at a level of 1%. The R^2 of the regression is 0.0797. The regression should be free of reverse causality since it is difficult to imagine why discounting behavior can improve or reduce memorizing ability. The result is consistent with the theoretical prediction: the memorize capacity is positively correlated with discounting rate.

[2] We did not elicit risk preference using the Holt and Laury (2002) form, as Anderson et al. (2008) argues that the estimated discounting rate may be inflated if not accompanied by elicitation of risk preference. Our result is reassuring since the elicited discounting rate is very close to normal discounting rates used in the literature.

Discussions and implications

The above experiment supports our proposition that memory capacity is positively correlated with discounting rate at the individual level and the concept of memory utility is evidenced.

We now could further extend our theory by specifying a utility function. Assuming the utility function is $u(c) = \ln(c)$, maximizing the utility in Equation (1) in the case of no memory utility yields

$$c_0 = \frac{1+r}{2+r} w_0 \quad . \tag{7}$$

Analogously, maximizing the utility in Equation (5), in the case of memory utility under the budget constraint (2), we have

$$c_0^* = \frac{1+r+\rho}{2+r+\rho} w_0 \tag{8}$$

Comparing Equation (7) with (8), we obtain $c_0^* > c_0$ for $\rho > 0$. That is

Proposition 2:

When there is memory utility, consumers tend to allocate more budget to the current period, compared with the case without memory utility.

Intuitively, consumers with memory utility could obtain more utility when more budgets are allocated to the period 0, which could then compensate the utility loss in period 1 through memory utility.

In addition, Equation (8) also shows that

$$\frac{\partial c_0^*}{\partial \rho} > 0 .$$

This yields

Proposition 3:

Consumers with higher memory capacity allocate more budgets to the current period, and save less for the future when memory utility exists.

Also, the fact that more budgets are allocated to current period implies that the consumer has a higher discounting rate. Thus, Proposition 3 is consistent with Proposition 1.

In practice, people tend to spend a lot of money on weddings and for tourism, particularly young people, because they could yield ample memory utility, which could contribute to later utility.

Conclusion

Adopting the concept of "memory utility" proposed by Gilboa, Postlewaite and Samuelson (2015) , that current utility depends not only on current consumption but also on past consumption, we explore the relationship between memory and discounting behavior by building a simple two-period model and by comparing its predictions with experimental data. The model predicts that in most cases, the strength of memory should be positively correlated with discount rate, which is well supported by the experimental data.

Our work is potentially useful for building the psychological foundation of discounting behavior. Meanwhile, due to the simplicity of the present study, we cannot set up a full discounting curve that incorporates other factors such as hyperbolic discounting (Laibson, 1997) and present bias (Chark et al. 2015).

For future extension of our research, it may be useful to compare memory utility for positive versus negative experiences. Chew et al. (2014) find that people have a strong tendency to forget negative past events and exhibit false memory in favor of positive events. If memory capacity is influenced by the nature of the event, it may also be translated to different observed discount rate.

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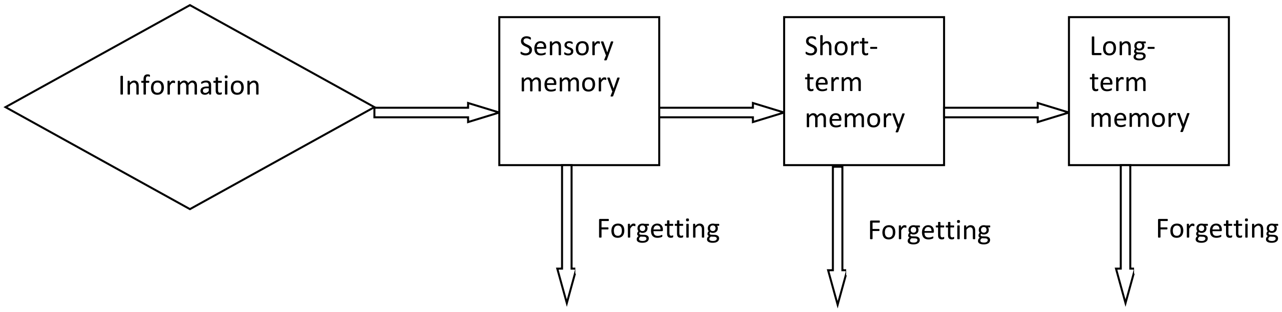

Figure 1: Information Process and Memory

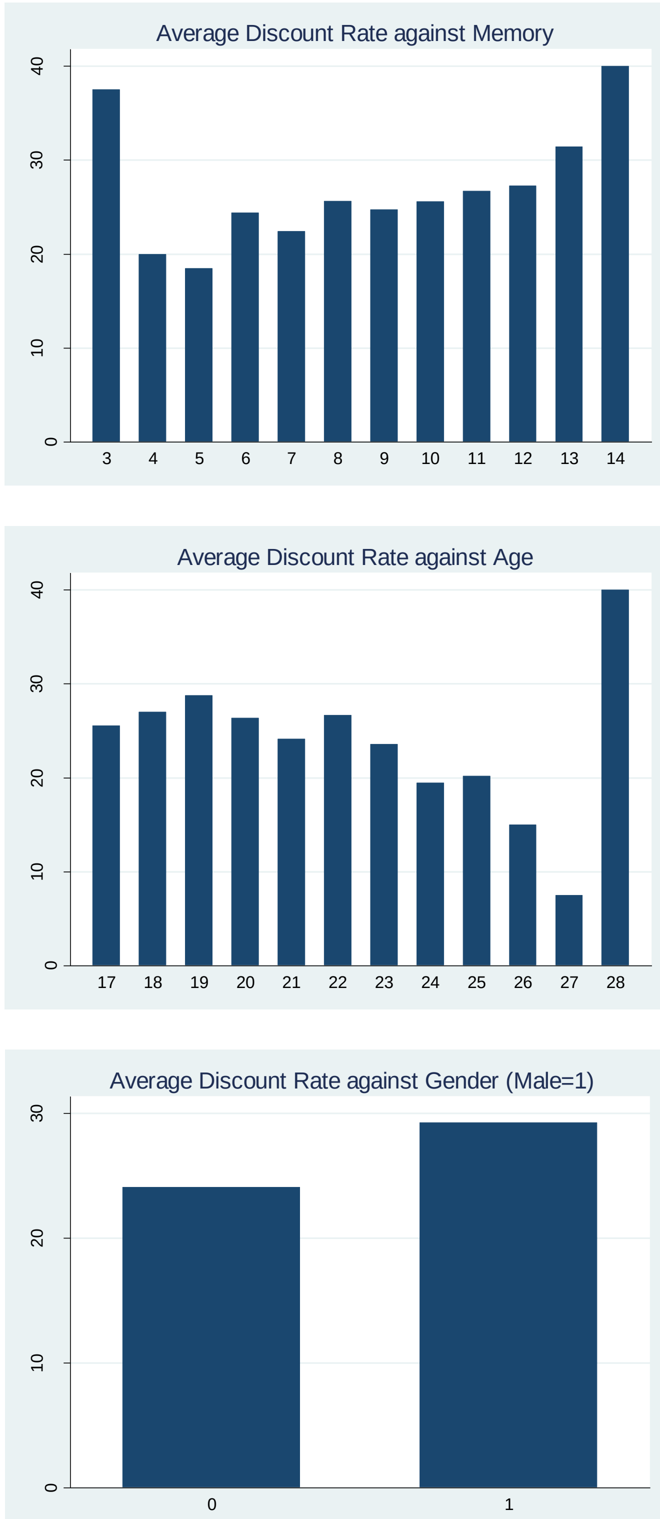

Figure 2: The average discount rate for each memory level, age and gender.

Table 1: Regression results for the experimental results

Variable	Coefficient	Std. Err.	t-statistic	P-value
Intercept	42.1877	6.0083	7.02	0.0000
Memory	0.6772	0.3014	2.25	0.0250
Male	5.2682	1.2058	4.37	0.0000
Age	-1.1809	0.2460	-4.80	0.0000

Appendix

Appendix 1:

Task to elicit time preference.

Suppose you are going to receive an amount of money around 3000 yuan. There are two options for you to receive it: Option A allows you to receive 3000 yuan in one month, and Option B allows you to receive 3000 yuan plus some interest payment in seven months. Please make a choice between A and B in the 10 pairs of choices below:

	Option A	**Option B**	**Yearly Interest Rate**	**Effective Yearly Interest Rate**	**Your Choice**	
	In 1 month Amount	In 7 months Amount	(%)	（%）	（Circle A or B）	
1	3000	3075	5	5.09	A	B
2	3000	3152	10	10.38	A	B
3	3000	3229	15	15.87	A	B
4	3000	3308	20	21.55	A	B
5	3000	3387	25	27.44	A	B
6	3000	3467	30	33.55	A	B
7	3000	3548	35	39.87	A	B
8	3000	3630	40	46.41	A	B
9	3000	3713	45	53.18	A	B
10	3000	3797	50	60.18	A	B

Appendix 2:

Instructions for memory measurement task

Now you are going to watch 13 slides in a sequence. On each slide there is a number. Please write down the numbers on the slides in the right sequence.

Numbers on the slides:

69, 929, 1021, 34634, 943453, 7374885, 69358267, 699875725, 6655803001, 26656897198, 661518840995, 1285246589042, 91431501977497.